NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE

No. 1439

COMPRESSIVE STRENGTH OF 24S-T ALUMINUM-ALLOY FLAT PANELS WITH LONGITUDINAL FORMED HAT-SECTION STIFFENERS HAVING A RATIO OF STIFFENER THICKNESS TO SKIN THICKNESS EQUAL TO 1.00

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Langley Memorial Aeronautical Laboratory
Langley Field, Va.

Washington
September 1947

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SUMMARY

Results are presented for a part of a test program on 24S-T aluminum-alloy flat compression panels with longitudinal formed hat-section stiffeners. This part of the program is concerned with panels in which the thickness of the stiffener material is equal to the thickness of the skin. The results, presented in tabular and graphical form, show the effect of the relative dimensions of a panel on the buckling stress and the average stress at maximum load. Comparative envelope curves are presented for hat-stiffened and Z-stiffened panels having the same ratio of stiffener thickness to sheet thickness. These curves provide some indication of the relative structural efficiencies of the two types of panel.

INTRODUCTION

An extensive experimental investigation of the strength of 24S-T aluminum-alloy flat compression panels with longitudinal formed Z-section stiffeners was reported in reference 1. The data presented in reference 1 were reworked on the basis of a selected design parameter and were used for the preparation of design charts in reference 2. A similar investigation is now being conducted on panels of the same material with formed hat-section stiffeners for the purpose of making design charts like those of reference 2 and also to provide an eventual complete comparison of the structural efficiencies of the two types of stiffener.

The initial part of the test program on panels with hat-section stiffeners was reported in reference 3. The second part of this test program has now been completed and the results are presented herein; this part of the program is concerned with panels in which the thickness of the stiffener material is equal to the thickness of the skin.

SYMBOLS

Symbols for dimensions of panel cross sections are shown in figure 1. In addition, the following symbols are used:

P_i compressive load per inch of panel width, kips per inch

A_i cross-sectional area per inch of panel width, or equivalent thickness of panel, inches

L length of panel, inches

c coefficient of end fixity in Euler column formula

σ_{cr} local-buckling stress of skin or stiffener, ksi

$\bar{\sigma}_f$ average stress at failure, ksi

TEST SPECIMENS

The test panels each had six stiffeners. Both the skin and stiffeners were made of 24S-T aluminum-alloy sheet with the grain of the material parallel to the longitudinal axis of the panels. The with-grain compressive yield strength of the skin material ranged between 42.7 ksi and 45.4 ksi with an average of 43.9 ksi and that of the stiffener material before forming varied between 42.8 ksi and 45.3 ksi with an average of 44.0 ksi.

For the tests reported herein, the nominal thickness of the stiffener material and the skin material was 0.040 inch. The nominal ratio of the stiffener thickness to the skin thickness t_W/t_S was therefore constant at 1.00. With these dimensions known, numerical values for all cross-sectional dimensions can be found by means of the proper dimension ratios. The stiffeners were formed from flat sheet to an inside radius of 0.125 inch for all bends $\left(\frac{r_A}{t_W} \approx 3\right)$. The width of the attachment flange b_A was 0.65 inch for all stiffeners. The rivet lines on the stiffeners were on the longitudinal center lines of the attachment flanges. A typical panel cross section is shown in figure 1.

The NACA flush-rivet method (reference 4) was employed in the construction of the test specimens. The rivet holes were countersunk on the skin side of the panel to a depth of three-fourths of the skin thickness, the countersink having an included angle of 60°. Ordinary flat-head A17S-T aluminum-alloy rivets were inserted from the stiffener side, and the shanks were upset into the countersunk cavity. The protruding part of the upset shank was then milled off to provide a smooth surface. The rivet diameter was 1/8 inch and the pitch was 1/2 inch.

In order to ensure uniform bearing in the testing machine, the ends of each panel were ground flat and perpendicular to the longitudinal axis of the panel.

METHOD OF TESTING

The specimens were tested flat-ended, without side support, in the 1,200,000-pound-capacity testing machine at the Langley structures research laboratory. For the testing machine, within the range of loads used, the indicated load is within one-half of 1 percent of the applied load. Provisions were made for setting the specimens in the testing machine in such a manner as to maintain the flatness of the panels and afford uniform bearing at the ends. Figure 2 shows a panel prepared for testing.

Resistance-type wire strain gages were used to measure strains at successive increments of load. The gages were placed in those locations on the stiffeners and skin where buckles were expected to appear first.

RESULTS AND CONCLUSIONS

Results and conclusions for hat-stiffened panels.- By use of the method set forth in reference 5, it has been found that for panels similar to those of this investigation, which were tested flat-ended in the same testing machine, the coefficient of end fixity c is about 3.75. This value of c was consequently used in reducing the present data.

In order to obtain the average stress at failure $\bar{\sigma}_f$, the load at which failure occurred was divided by the cross-sectional area of the panel. No adjustment was made to offset the effect of having an unequal number of stiffeners and bays. The effect of such an adjustment would be to decrease slightly the values of $\bar{\sigma}_f$ at high values of $\frac{b_S}{t_S}$ and $\frac{P_i}{L/\sqrt{c}}$. Inasmuch as the purpose of the present paper is to present test data, however, and not to prepare final design charts, the adjustment was considered unwarranted.

In order to obtain the buckling stress for each panel, the strain-gage readings were plotted in the form of load-strain curves and the buckling load was taken as the load beyond which there was a decrease in local compressive strain, as shown by the reading of a gage near the crest of a buckle. The buckling load was divided by the cross-sectional area of the panel to give the observed buckling stress. An adjustment was made in the observed buckling stress to correct for slight variations from the nominal dimensions of the specimens. The method for making the adjustment is explained in the appendix of reference 3.

Because stresses are determined by the relative rather than the absolute dimensions of the panels, nondimensional ratios are used in presenting the data. In reference 2 the quantity $\frac{P_i}{L/\sqrt{c}}$ is developed as a suitable parameter against which to plot the average stress at maximum load. This parameter is used in plotting the results of the tests in the present investigation.

Tables 1 to 4 (facing figs. 3 to 6) list both the observed and the adjusted buckling stresses, together with the average stress at failure, for corresponding values of $\frac{P_i}{L/\sqrt{c}}$. The ratio A_i/t_S is included in the tables for convenience in making comparisons between the hat-stiffened test panels and the Z-stiffened panels of reference 2. Values of $L/\sqrt{c}$ are also given.

In figures 3 to 6 the average stress at failure is plotted against $\frac{P_i}{L/\sqrt{c}}$ for the various dimension ratios used. The initial dashed parts of the curves were computed from the column strength of the panels based on nominal dimensions and a column curve obtained from equations (5) and (6) and table 1 of reference 6; the solid-line parts of the curves were drawn through the experimental test points.

The primary results of this investigation are to be found in the numerical values of test data contained in the tables and figures. In addition, the following general conclusions may be drawn regarding the effect of the various dimension ratios on the strength of the test panels. It is assumed that as each dimension ratio is changed all others remain constant. These general conclusions can only be considered to apply within the range of panels tested.

1. When the parameter $\frac{P_i}{L/\sqrt{c}}$ has a very low value (long panels that fail by column bending), the stress developed by the panels increases with an increase in b_W/t_W because increasing the height of the stiffeners provides increased column strength. For high values of $\frac{P_i}{L/\sqrt{c}}$ (short panels that fail by local buckling), however the stress decreases as b_W/t_W increases because increasing the height of the stiffeners decreases the local-buckling strength.

2. At very high values of $\frac{P_i}{L/\sqrt{c}}$ (short panels that fail by local buckling), an increase in the ratio b_H/b_W tends to decrease the stress developed by the panels because increasing the width of the stiffeners decreases the local-buckling strength.

3. Except at very low values of $\frac{P_i}{L/\sqrt{c}}$ (long panels that fail by column bending), the stress developed by the test panels increases as b_S/t_S is decreased because decreasing the stiffener spacing increases the local-buckling strength.

<u>Comparison of hat-stiffened and Z-stiffened panels</u>.- In reference 2, envelope curves of $\bar{\sigma}_f$ against $\frac{P_i}{L/\sqrt{c}}$ were presented for Z-stiffened panels with four values of the ratio t_W/t_S. Although the present paper is based on far less data than was reference 2, it is possible to prepare a similar envelope curve based on the present tests. In figure 7, such an envelope curve

is compared with that for Z-stiffened panels with $\frac{t_W}{t_S} = 1.00$. It should not be inferred that the ratio t_W/t_S is considered a proper basis for final comparison; a better comparison would be provided by actual comparative designs, or by curves of the type presented in figures 18 to 20 of reference 7. The present data, however, are too limited for such an expedient and consequently t_W/t_S is used to afford a tentative evaluation.

The most immediately evident feature of figure 7 is that the values of $\bar{\sigma}_f$ for hat-stiffened panels are appreciably lower than those for Z-stiffened panels at high values of $\frac{P_i}{L/\sqrt{c}}$. Several factors (see reference 3) could be responsible for this difference. It is apparent from figure 1 that the clear distance between the sides of adjacent stiffeners is appreciably greater than b_S, the distance from rivet line to rivet line. In fact, had b_S been measured as the clear distance between the sides of the stiffeners, all values of b_S/t_S would have been increased by about 14. On this basis, the lowest value of b_S/t_S included in the present program is 39, whereas the Z-stiffened panels included values of this ratio down to 25. It is quite likely that data for hat-stiffened panels with values of b_S/t_S lower than 25 (measured as in fig. 1) would produce curves that would rise above the envelope curve for hat-stiffened panels in figure 7, at high values of $\frac{P_i}{L/\sqrt{c}}$.

There was a factor in the present tests, however, which tended to improve the efficiency of the hat-stiffened panels as compared with that of the Z-stiffened panels of reference 2; the rivets were, relative to the sheet gages, larger and more closely spaced than those in the Z-stiffened panels. The data of reference 8 indicate that stronger riveted joints in the Z-stiffened panels would have brought about some increase in strength at high values of $\frac{P_i}{L/\sqrt{c}}$.

On the other hand, it is pointed out in reference 2 that, for $\frac{t_W}{t_S} = 1.00$, the curves for values of $\frac{b_S}{t_S} = 25$ that establish the top part of the envelope curve for Z-stiffened panels have been obtained entirely by extrapolation. Check tests made since the preparation of the curves in reference 2 showed that, for $\frac{t_W}{t_S} = 1.00$, $\frac{b_S}{t_S} = 25$, and $\frac{b_W}{t_W} = 20$, the highest attainable $\bar{\sigma}_f$ was equal to 40.2 ksi. A corrected envelope curve, based on these check tests would fall only slightly above the curve for hat-stiffened panels.

Because of the several factors discussed that tend to alter the comparison of envelopes given in figure 7, truly comparable envelope curves for hat- and Z-stiffened panels, for $\frac{t_W}{t_S} = 1.00$, might be more favorable to the hat-stiffened panels than those given in figure 7.

Langley Memorial Aeronautical Laboratory
National Advisory Committee for Aeronautics
Langley Field, Va., June 11, 1947

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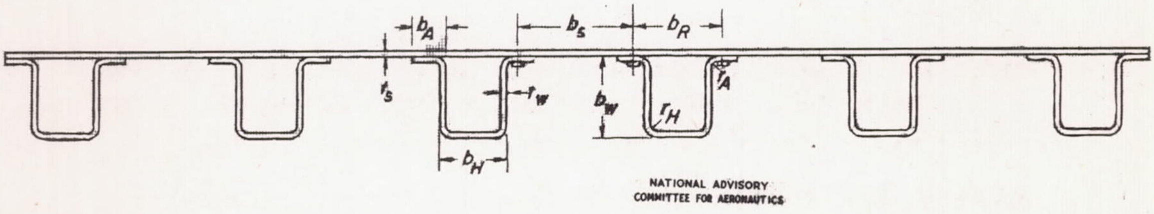

Figure 1.- Cross section of a test panel.

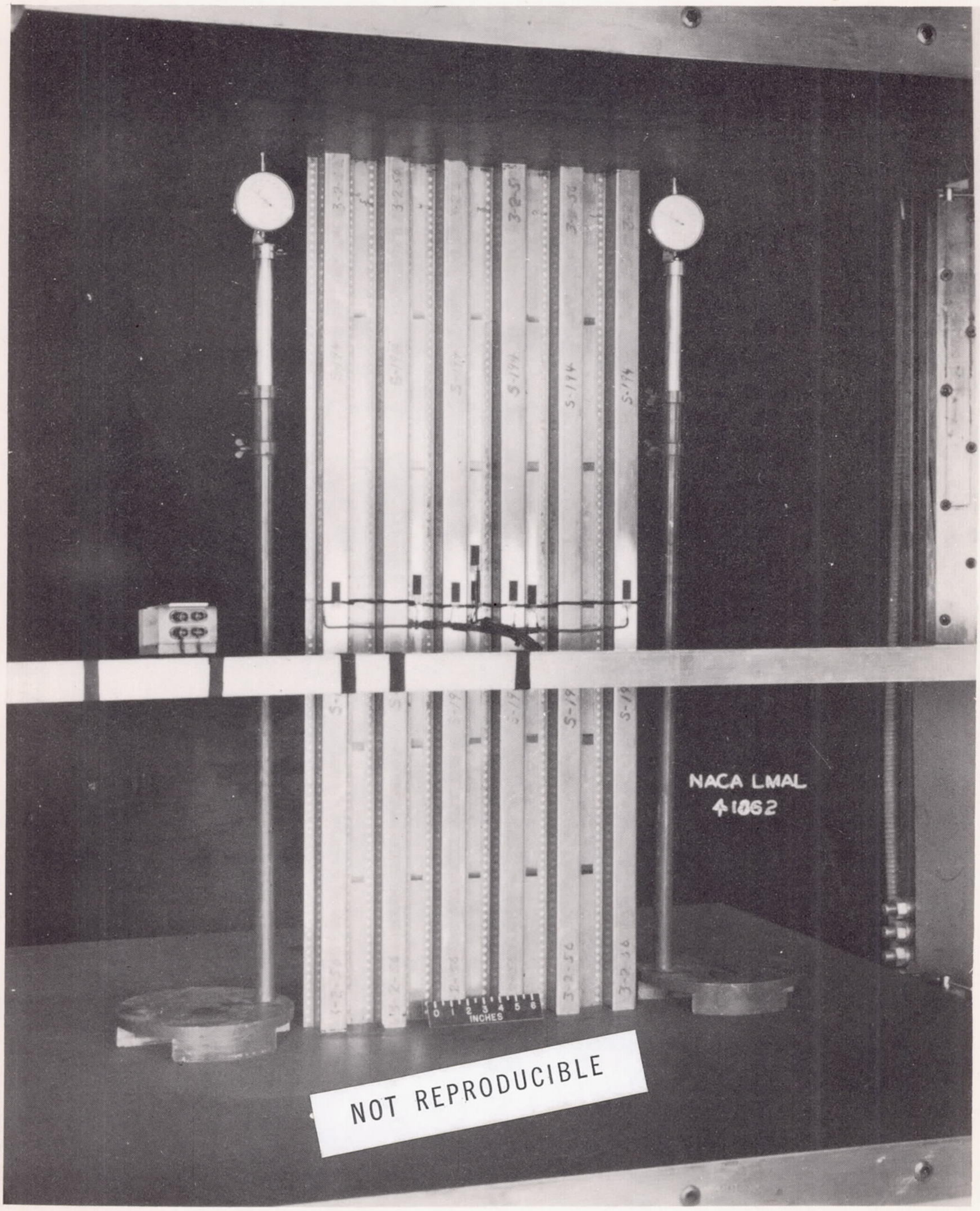

Figure 2.- Panel before testing.

TABLE 1

TEST DATA FOR FLAT PANELS WITH HAT-SECTION STIFFENERS WITH $\frac{b_H}{b_W} = 0.6$

$\left[\frac{t_W}{t_S} = 1.00\right]$

$\frac{b_W}{t_W}$	σ_{cr} (ksi) Observed	σ_{cr} (ksi) Adjusted	$\bar{\sigma}_f$ (ksi)	$\frac{L}{\sqrt{c}}$ (in.)	$\frac{P_1}{L/\sqrt{c}}$ (ksi)	$\frac{A_1}{t_S}$
$\frac{b_S}{t_S} = 25$						
20	37.0 38.4 31.7 ----	35.5 37.6 30.7 ----	39.7 39.1 32.9 20.0	4.23 7.03 11.20 16.78	0.918 .545 .288 .117	2.449
30	---- ---- ---- 17.7	---- ---- ---- 17.0	36.3 35.9 32.6 20.3	6.81 11.33 18.20 27.16	.586 .349 .197 .082	2.751
40	28.6 25.3 27.9 19.2	29.5 26.2 28.4 17.4	30.7 30.8 30.4 21.7	9.37 15.68 25.02 37.54	.392 .235 .145 .069	2.995
60	14.8 13.4 13.2 11.8	16.1 14.1 14.1 12.2	23.6 23.9 22.4 17.9	14.49 24.05 38.50 57.73	.219 .134 .078 .042	3.369
$\frac{b_S}{t_S} = 50$						
20	18.0 19.4 21.1 20.2	18.9 19.7 21.8 19.6	33.6 34.2 29.8 20.9	3.96 6.63 10.66 15.95	0.671 .408 .221 .104	1.974
30	17.2 17.8 20.1 19.8	17.1 18.8 20.5 20.7	32.0 31.2 29.7 21.4	6.61 11.00 17.54 26.34	.430 .252 .150 .072	2.219
40	17.9 18.4 19.1 20.3	18.4 18.9 18.4 20.5	27.5 28.8 26.0 22.2	9.19 15.34 24.53 36.71	.291 .182 .103 .059	2.430
60	14.9 14.8 15.1 14.4	14.2 14.8 14.4 13.4	22.6 22.0 21.8 18.6	14.40 23.94 38.18 57.20	.175 .102 .064 .036	2.780

$\frac{b_W}{t_W}$	σ_{cr} (ksi) Observed	σ_{cr} (ksi) Adjusted	$\bar{\sigma}_f$ (ksi)	$\frac{L}{\sqrt{c}}$ (in.)	$\frac{P_1}{L/\sqrt{c}}$ (ksi)	$\frac{A_1}{t_S}$
$\frac{b_S}{t_S} = 35$						
20	29.1 29.0 30.6 19.7	25.8 25.9 25.4 16.4	37.1 35.7 31.6 20.4	4.07 6.88 10.91 16.37	0.806 .459 .256 .110	2.212
30	28.0 30.6 30.4 22.0	25.1 25.1 26.6 17.7	33.2 32.0 31.1 22.9	6.71 11.19 17.88 26.89	.493 .285 .174 .085	2.491
40	26.7 25.6 26.3 22.5	23.4 22.2 23.1 26.2	28.4 28.2 28.2 23.3	9.30 15.49 24.85 37.23	.332 .198 .124 .068	2.722
60	13.8 14.9 15.2 16.0	13.1 14.2 14.7 16.4	22.1 22.3 21.4 19.9	14.42 23.98 38.40 57.57	.190 .115 .069 .043	3.091
$\frac{b_S}{t_S} = 75$						
20	8.2 11.5 11.4 9.5	8.4 12.0 11.5 9.7	30.3 29.7 28.1 19.7	3.78 6.34 10.11 15.04	0.555 .325 .193 .091	1.733
30	10.4 10.3 8.9 14.4	10.9 10.9 9.3 15.4	30.0 31.0 27.9 19.3	6.40 10.63 16.98 25.38	.363 .225 .127 .059	1.935
40	12.7 9.6 11.5 10.9	13.2 10.5 12.0 11.8	27.2 26.8 27.5 19.8	8.88 15.00 23.80 35.86	.259 .151 .098 .047	2.115
60	16.5 11.8 9.7 13.6	17.5 12.4 10.2 14.6	21.6 21.6 21.3 17.6	14.03 23.54 37.68 56.55	.149 .089 .055 .030	2.423

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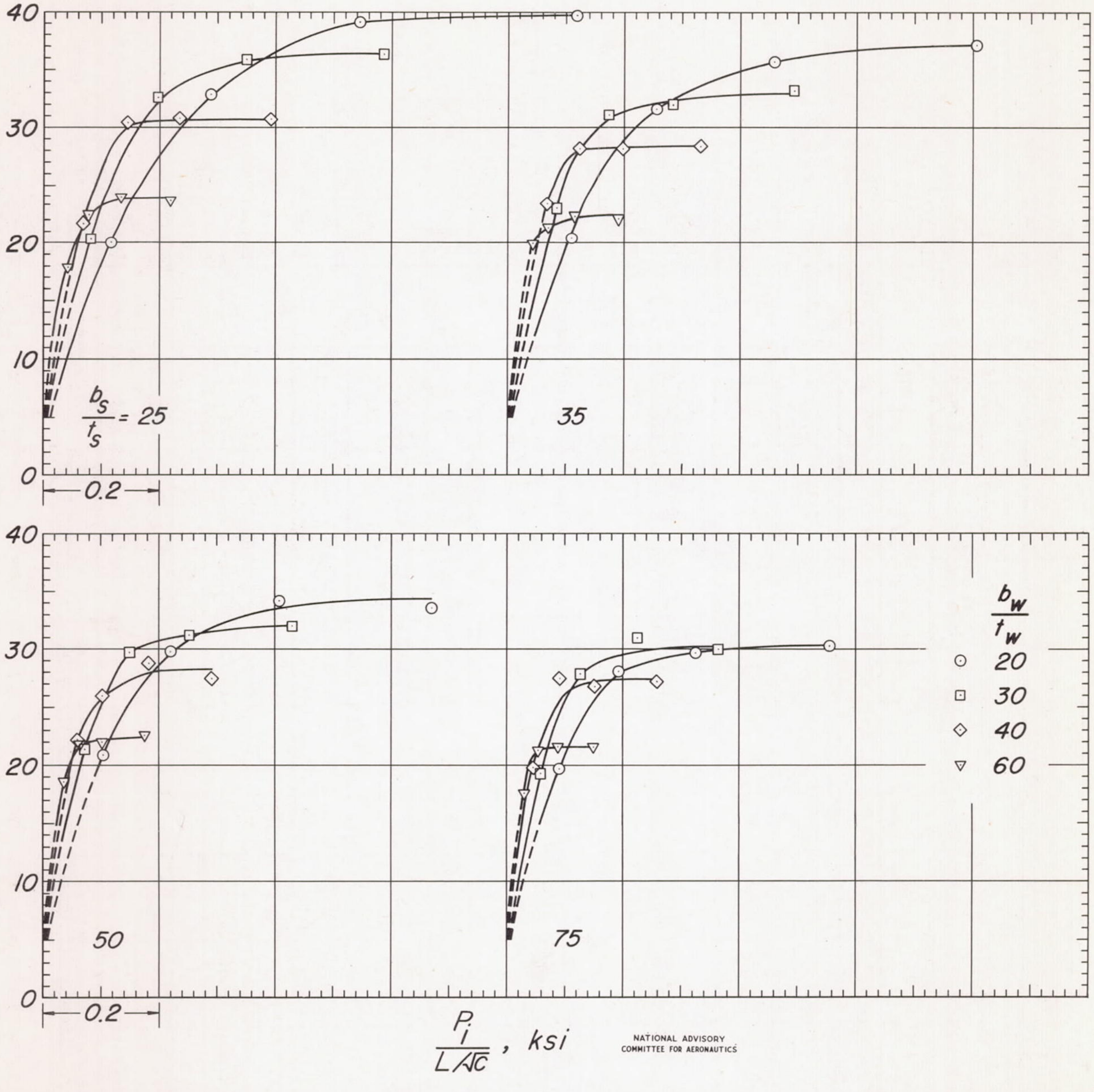

Figure 3.- Compressive strength of flat panels with hat-section stiffeners. $\frac{t_W}{t_S} = 1.00$; $\frac{b_H}{b_W} = 0.6$.

TABLE 2

TEST DATA FOR FLAT PANELS WITH HAT-SECTION STIFFENERS WITH $\frac{b_H}{b_W} = 0.8$

$\left[\frac{t_W}{t_S} = 1.00\right]$

$\frac{b_W}{t_W}$	σ_{cr} (ksi) Observed	σ_{cr} (ksi) Adjusted	$\bar{\sigma}_f$ (ksi)	$\frac{L}{\sqrt{c}}$ (in.)	$\frac{P_1}{L/\sqrt{c}}$ (ksi)	$\frac{A_1}{t_S}$
$\frac{b_S}{t_S} = 25$						
20	35.8 36.9 31.0 ----	36.5 36.3 32.0 ----	38.6 37.8 32.6 20.4	4.42 7.37 11.75 17.73	0.845 .495 .268 .111	2.416
30	---- 33.4 ---- 19.6	---- 30.7 ---- 16.1	35.4 35.3 34.6 21.5	7.05 11.78 18.74 28.29	.538 .322 .198 .082	2.680
40	27.3 26.1 27.4 20.6	29.0 27.4 25.8 18.8	29.2 28.9 29.0 21.7	9.71 16.21 25.96 38.94	.347 .206 .128 .064	2.885
60	13.3 13.5 12.4 11.8	14.0 14.6 13.4 12.6	22.0 21.7 20.2 15.1	14.86 24.87 39.85 59.70	.188 .111 .064 .032	3.180
$\frac{b_S}{t_S} = 50$						
20	21.2 19.2 19.9 19.9	22.0 19.6 20.6 20.7	33.8 33.4 28.6 21.3	4.24 6.99 11.22 16.85	0.630 .377 .201 .100	1.975
30	19.1 17.3 19.1 20.0	19.0 17.9 17.6 20.2	30.7 30.3 30.0 21.2	6.88 11.5 18.3 27.5	.394 .233 .144 .068	2.204
40	17.7 20.0 18.6 20.4	18.1 19.0 18.7 19.9	27.7 28.0 26.7 21.4	9.58 15.92 25.46 38.13	.277 .168 .101 .054	2.395
60	14.1 13.6 14.5 14.3	13.1 13.0 14.4 13.3	20.9 20.7 20.4 16.9	14.84 24.68 39.52 59.19	.152 .090 .056 .031	2.695

$\frac{b_W}{t_W}$	σ_{cr} (ksi) Observed	σ_{cr} (ksi) Adjusted	$\bar{\sigma}_f$ (ksi)	$\frac{L}{\sqrt{c}}$ (in.)	$\frac{P_1}{L/\sqrt{c}}$ (ksi)	$\frac{A_1}{t_S}$
$\frac{b_S}{t_S} = 35$						
20	32.1 28.8 30.06 20.6	29.5 25.7 25.7 18.3	36.9 34.8 31.3 21.7	4.32 7.18 11.54 17.33	0.751 .427 .239 .110	2.199
30	28.5 26.1 26.6 21.7	24.4 23.7 30.6 18.5	32.1 30.3 28.9 22.9	6.99 11.70 18.67 27.98	.450 .254 .152 .080	2.450
40	19.9 24.9 23.7 21.5	21.3 27.7 26.8 24.4	26.6 27.3 26.4 22.4	9.62 16.09 25.73 38.64	.293 .180 .109 .061	2.652
60	11.2 13.1 12.8 13.7	13.0 12.5 12.1 13.1	20.0 21.0 20.1 18.0	14.86 21.97 39.69 59.49	.159 .113 .060 .036	2.956
$\frac{b_S}{t_S} = 75$						
20	11.0 12.0 11.9 10.1	11.3 12.7 12.4 10.6	31.1 30.2 27.6 20.0	4.04 6.71 10.74 16.11	0.537 .314 .179 .087	1.743
30	11.2 11.8 9.6 9.6	11.4 12.4 10.2 10.2	28.8 30.0 26.6 20.6	6.71 11.12 17.77 26.66	.324 .203 .113 .058	1.882
40	11.9 11.5 8.5 11.8	12.6 11.3 9.0 12.7	25.6 25.2 25.5 20.4	9.38 15.50 24.91 37.35	.230 .137 .086 .046	2.107
60	9.8 13.0 11.8 13.6	10.1 13.5 12.3 14.0	20.6 20.6 19.1 15.8	14.52 24.39 39.06 58.48	.135 .080 .047 .026	2.386

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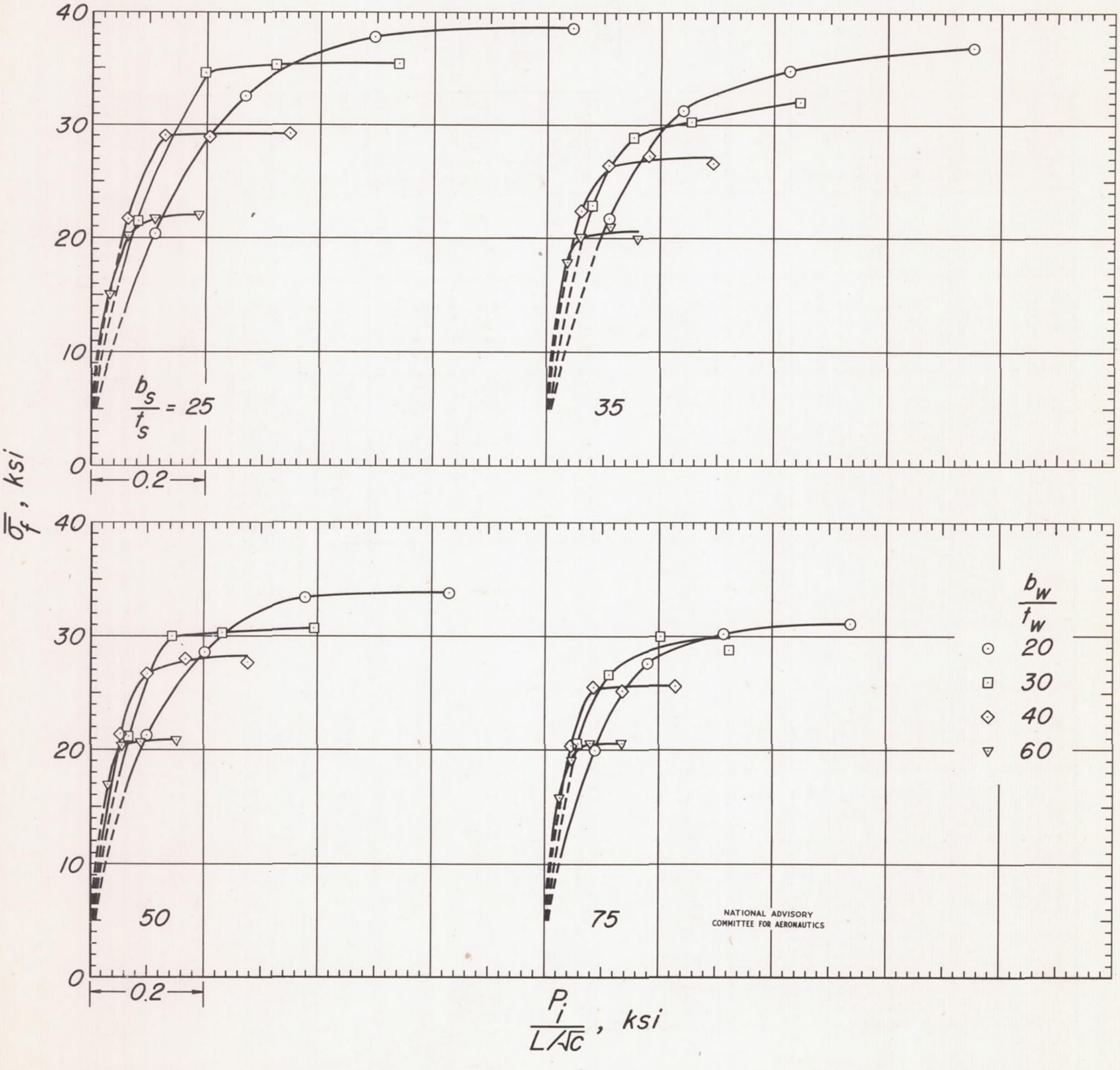

Figure 4.- Compressive strength of flat panels with hat-section stiffeners. $\frac{t_w}{t_s} = 1.00$; $\frac{b_H}{b_w} = 0.8$.

TABLE 3

TEST DATA FOR FLAT PANELS WITH HAT-SECTION STIFFENERS WITH $\frac{b_H}{b_W} = 1.0$

$$\left[\frac{t_W}{t_S} = 1.00\right]$$

$\frac{b_W}{t_W}$	σ_{cr} (ksi)		$\bar{\sigma}_f$	$\frac{L}{\sqrt{c}}$	$\frac{P_1}{L/\sqrt{c}}$	$\frac{A_1}{t_S}$
	Observed	Adjusted	(ksi)	(in.)	(ksi)	
$\frac{b_S}{t_S} = 25$						
20	37.4 35.8 ---- ----	35.9 34.8 ---- ----	38.0 37.7 33.0 21.2	4.61 7.63 12.28 18.40	0.787 .472 .257 .110	2:388
30	30.2 30.8 ---- 20.6	27.7 27.9 ---- 18.9	33.4 32.8 31.5 22.1	7.31 12.16 19.44 29.25	.478 .283 .170 .079	2:620
40	24.8 21.0 22.0 21.0	22.3 16.7 26.2 19.3	27.4 27.5 26.2 22.5	10.01 16.68 26.71 39.97	.306 .184 .110 .063	2.795
60	11.8 12.1 11.4 11.0	12.4 12.6 12.1 11.7	20.7 21.0 19.0 14.4	15.31 25.49 40.77 61.14	.164 .100 .057 .028	3.038
$\frac{b_S}{t_S} = 50$						
20	18.2 21.4 19.1 20.5	19.0 21.5 19.5 21.1	32.5 33.4 29.7 22.1	4.43 7.31 11.71 17.64	0.580 .361 .200 .099	1.976
30	17.0 19.7 18.2 20.1	17.4 19.7 18.7 18.8	30.8 29.8 27.7 22.4	7.15 11.87 18.97 28.45	.377 .220 .128 .069	2.191
40	16.7 18.0 18.2 19.2	17.6 18.3 17.8 19.8	25.5 25.4 25.3 20.3	9.87 16.37 26.18 39.37	.244 .146 .091 .049	2.364
60	12.7 13.1 13.1 12.6	12.9 12.7 12.2 11.8	19.7 20.0 19.2 15.2	15.20 25.34 40.50 60.72	.136 .083 .050 .026	2.628

$\frac{b_W}{t_W}$	σ_{cr} (ksi)		$\bar{\sigma}_f$	$\frac{L}{\sqrt{c}}$	$\frac{P_1}{L/\sqrt{c}}$	$\frac{A_1}{t_S}$
	Observed	Adjusted	(ksi)	(in.)	(ksi)	
$\frac{b_S}{t_S} = 35$						
20	30.4 30.0 ---- 20.0	26.4 26.2 ---- 17.0	34.5 34.5 30.9 21.3	4.52 7.51 12.07 18.09	0.669 .402 .224 .103	2.188
30	26.4 28.1 27.6 21.6	23.6 25.2 26.0 25.2	30.2 29.3 29.0 22.5	7.24 12.07 19.33 28.95	.404 .235 .145 .075	2.416
40	19.3 19.3 18.4 20.1	21.5 21.7 20.3 23.1	25.5 25.1 25.0 21.1	9.95 16.61 26.50 39.74	.263 .157 .098 .055	2.595
60	10.6 10.7 10.0 11.7	10.4 11.6 10.9 11.2	19.0 19.8 18.2 15.6	15.25 25.46 40.72 61.00	.142 .089 .051 .029	2.851
$\frac{b_S}{t_S} = 75$						
20	11.0 10.5 11.3 11.1	11.8 11.2 11.9 11.8	31.1 29.3 27.9 20.4	4.23 7.05 11.23 16.56	0.515 .291 .174 .086	1.753
30	10.2 10.2 11.7 11.6	10.9 10.7 12.6 12.1	28.8 26.9 26.9 21.0	7.00 11.54 18.46 27.65	.319 .181 .113 .059	1.938
40	10.3 8.8 10.1 10.8	10.8 9.4 10.8 11.2	23.3 23.9 24.2 19.5	9.65 16.00 25.71 38.52	.203 .126 .079 .042	2.100
60	9.2 10.6 9.9 14.2	10.1 10.8 10.4 14.8	19.6 19.4 17.8 14.3	15.05 25.08 40.18 60.11	.123 .073 .042 .022	2.355

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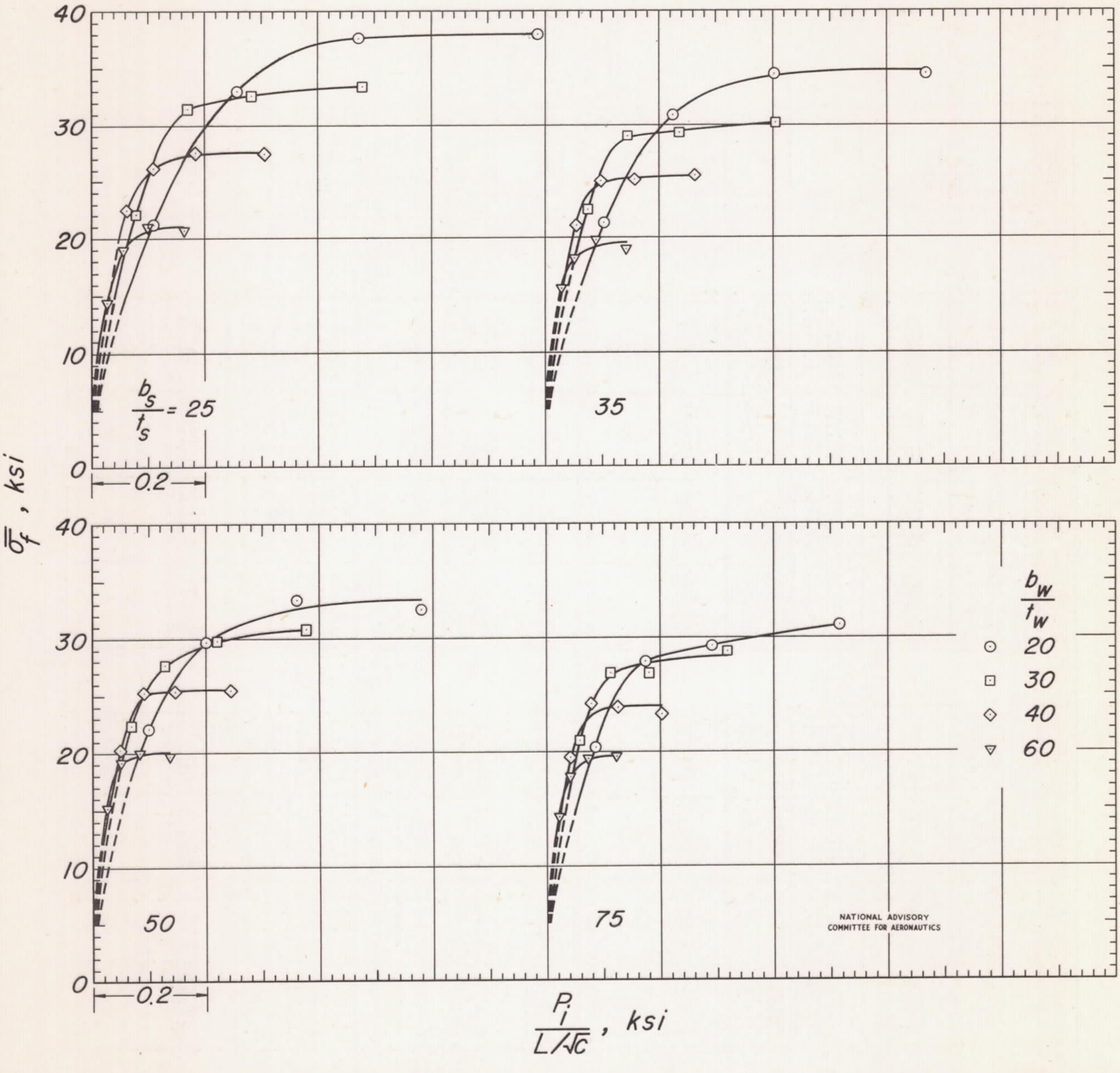

Figure 5.- Compressive strength of flat panels with hat-section stiffeners.

$\frac{t_W}{t_S} = 1.00; \ \frac{b_H}{b_W} = 1.0.$

TABLE 4

TEST DATA FOR FLAT PANELS WITH HAT-SECTION STIFFENERS WITH $\frac{b_H}{b_W} = 1.2$

$\left[\frac{t_W}{t_S} = 1.00\right]$

$\frac{b_S}{t_S} = 25$

$\frac{b_W}{t_W}$	σ_{cr} (ksi) Observed	σ_{cr} (ksi) Adjusted	$\bar{\sigma}_f$ (ksi)	$\frac{L}{\sqrt{c}}$ (in.)	$\frac{P_1}{L/\sqrt{c}}$ (ksi)	$\frac{A_1}{t_S}$
20	35.0 34.6 31.7 18.6	33.6 33.0 30.1 18.6	36.7 35.7 32.6 20.2	4.76 7.89 12.68 18.92	0.729 .428 .243 .101	2.364
30	27.0 24.9 ---- ----	25.1 23.1 ---- ----	31.6 31.1 29.3 22.5	7.49 12.50 19.95 29.9	.434 .256 .151 .077	2.572
40	18.0 19.0 17.0 18.0	16.5 17.7 15.6 18.3	25.1 25.7 23.1 19.1	10.21 17.06 27.23 40.91	.268 .164 .092 .051	2.722
60	10.3 8.2 8.3 8.7	10.7 7.6 8.9 9.3	19.7 19.4 18.2 13.3	15.57 25.97 41.60 62.39	.148 .088 .051 .025	2.926

$\frac{b_S}{t_S} = 35$

$\frac{b_W}{t_W}$	σ_{cr} (ksi) Observed	σ_{cr} (ksi) Adjusted	$\bar{\sigma}_f$ (ksi)	$\frac{L}{\sqrt{c}}$ (in.)	$\frac{P_1}{L/\sqrt{c}}$ (ksi)	$\frac{A_1}{t_S}$
20	28.9 28.5 28.7 22.5	24.4 24.9 24.7 18.4	33.4 32.6 29.4 23.3	4.68 7.75 12.43 18.62	0.622 .367 .206 .109	2.178
30	20.6 21.5 20.2 21.4	23.4 23.8 23.0 24.2	28.9 28.3 27.4 22.4	7.43 12.41 19.81 29.73	.371 .218 .132 .072	2.387
40	14.5 15.5 16.3 19.1	14.0 17.1 18.2 18.5	24.1 23.1 23.2 19.6	10.17 16.92 27.15 40.72	.241 .139 .087 .049	2.545
60	6.0 8.9 9.4 8.2	6.4 9.7 9.2 9.0	18.2 18.6 17.7 14.3	15.58 25.98 41.56 62.24	.129 .079 .047 .025	2.767

$\frac{b_S}{t_S} = 50$

$\frac{b_W}{t_W}$	σ_{cr} (ksi) Observed	σ_{cr} (ksi) Adjusted	$\bar{\sigma}_f$ (ksi)	$\frac{L}{\sqrt{c}}$ (in.)	$\frac{P_1}{L/\sqrt{c}}$ (ksi)	$\frac{A_1}{t_S}$
20	18.0 19.8 16.7 19.5	19.2 21.0 17.0 19.4	31.9 32.0 30.1 22.5	4.58 7.59 12.18 18.28	0.551 .334 .196 .097	1.977
30	17.9 18.6 18.1 20.7	17.5 18.8 17.7 19.2	29.9 29.5 27.2 21.2	7.35 12.08 19.56 29.28	.354 .213 .121 .063	2.180
40	20.2 17.4 17.0 18.4	19.4 15.7 16.8 16.5	24.0 23.7 23.0 19.2	10.13 16.82 26.85 40.21	.222 .132 .080 .045	2.338
60	11.5 9.8 9.2 9.8	11.1 9.8 8.6 9.2	19.1 19.0 17.2 14.0	15.53 25.83 41.38 62.00	.127 .076 .043 .023	2.572

$\frac{b_S}{t_S} = 75$

$\frac{b_W}{t_W}$	σ_{cr} (ksi) Observed	σ_{cr} (ksi) Adjusted	$\bar{\sigma}_f$ (ksi)	$\frac{L}{\sqrt{c}}$ (in.)	$\frac{P_1}{L/\sqrt{c}}$ (ksi)	$\frac{A_1}{t_S}$
20	9.6 13.1 9.3 8.7	10.4 13.8 9.9 9.2	30.5 29.2 28.3 20.5	4.10 7.27 11.77 17.51	0.524 .283 .169 .083	1.762
30	8.7 10.5 11.4 11.2	9.2 11.0 11.8 11.9	28.1 27.7 25.2 19.0	7.17 11.88 19.00 28.57	.304 .181 .103 .052	1.941
40	11.0 8.4 8.5 10.3	11.8 9.0 8.8 11.1	23.2 22.9 22.4 17.4	9.87 16.41 26.43 39.58	.196 .117 .071 .037	2.094
60	8.4 8.5 9.0 7.1	9.0 9.0 9.1 6.8	18.6 17.8 17.4 12.3	15.41 25.55 40.97 61.43	.112 .065 .040 .019	2.329

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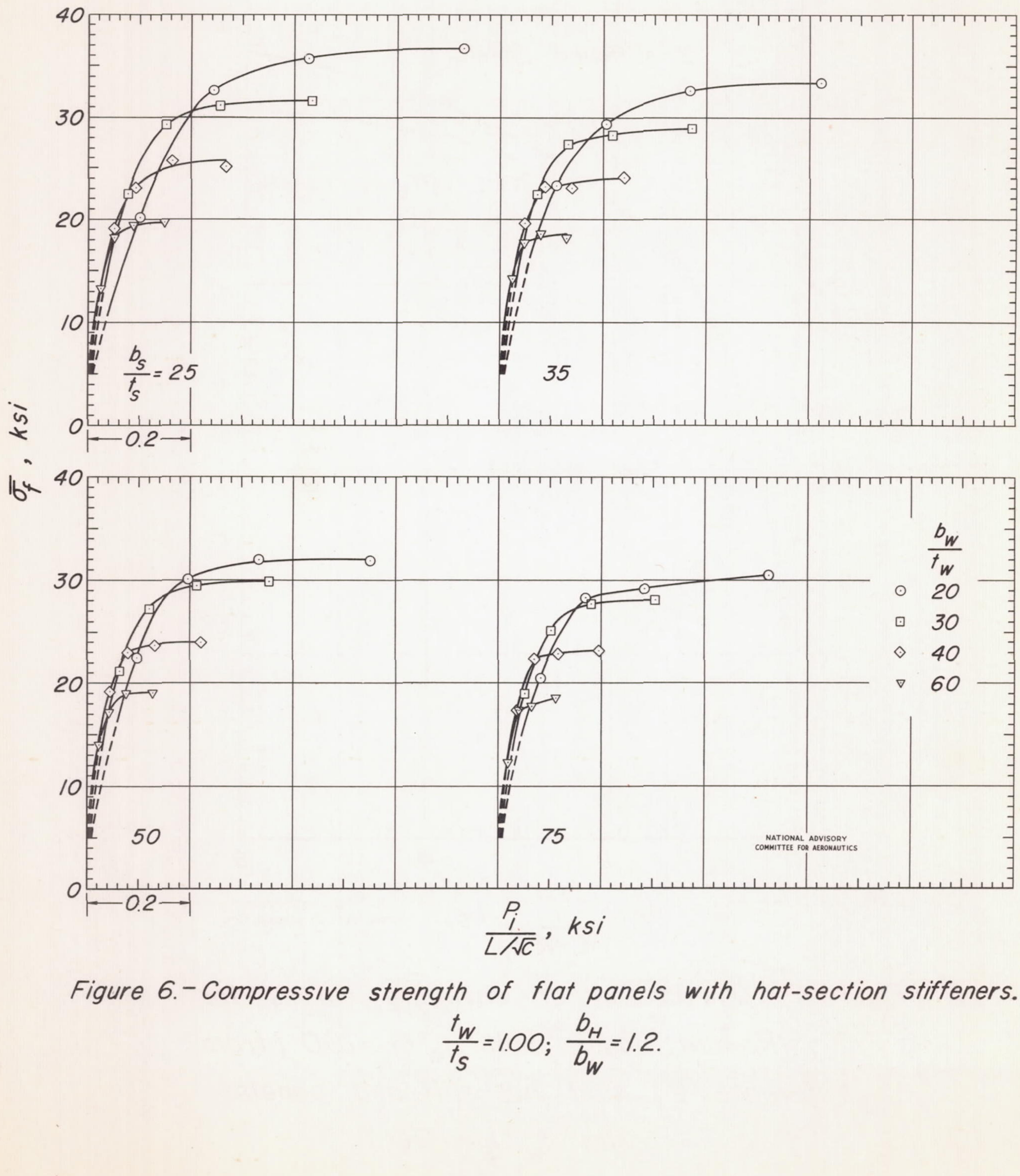

Figure 6.- Compressive strength of flat panels with hat-section stiffeners. $\frac{t_W}{t_S} = 1.00$; $\frac{b_H}{b_W} = 1.2$.

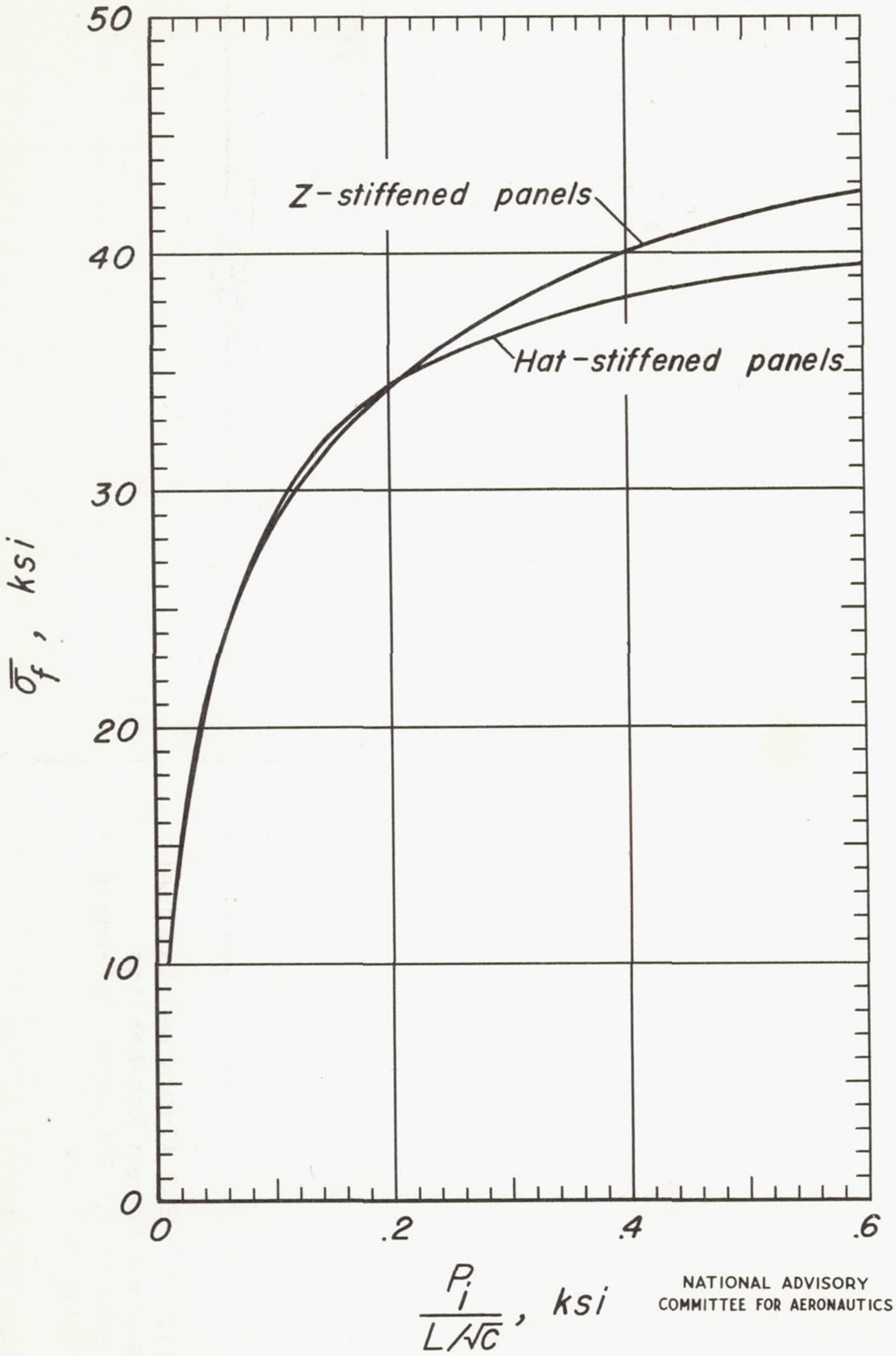

Figure 7.- Comparison of envelope curves for Z-stiffened panels with $t_W/t_S = 1.00$ (from reference 2) and hat-stiffened panels with $t_W/t_S = 1.00$.